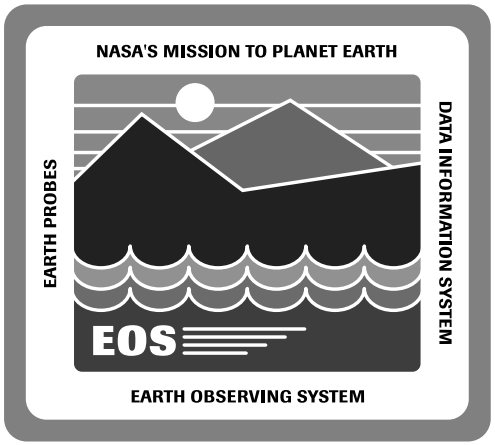
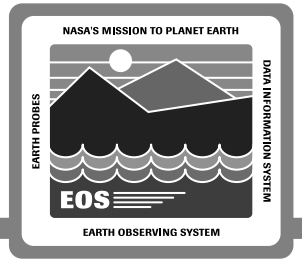


FOS Architecture

Andy Miller

System Design Review - 28 June 1994

FOS Architecture Outline



FOS Design Drivers

FOS Hardware Architectural Framework

FOS Software Architecture

FOS Architectural Concepts

- **Distributed Processing**
- **Multiple Operational Scenarios**

IST Characteristics

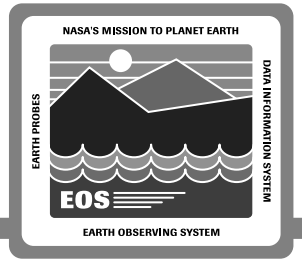
Key FOS Scenarios

- **External Interfaces**
- **End-to-End Scenarios**

FOS Design Drivers

FOS Drivers	FOS Approach
Provide integrated instrument and spacecraft operations	Flight Ops Team and PI/TLs provided: - Access to authorized FOS capabilities - Global visibility to FOS data - PI/TL access through IST
Integrate FOS functions seamlessly	- Provide integrated threads among scheduling, real-time, and analysis operations

FOS Design Drivers



FOS Drivers	FOS Approach
Support multiple, concurrent S/C and instrument operations	- Logical strings - Separate operations and support network components
Provide extensible and scalable architecture	
Provide architectural framework for evolution	- Encapsulation - Information hiding - Reuse

FOS Terms

Logical String

Consists of the set of software components that combine to perform telemetry and command processing for a spacecraft and its instrument manifest during a real-time contact, simulation, or historical replay.

- **A logical string is hosted on a set of hardware components,**
- **A set of hardware components can host multiple logical strings concurrently.**

Detailed Activity Schedule

An integrated, conflict-free schedule of activities that spans a 24-hour day.

Activity

Schedulable entity that represents tasking for a spacecraft subsystem, instrument, or a ground resource.

- **An activity is pre-defined in a data base, which consists of expansion instructions (i.e., lists of time-tagged commands or directives) and resource consumption parameters (e.g., power usage).**

FOS Terms

Ground Script

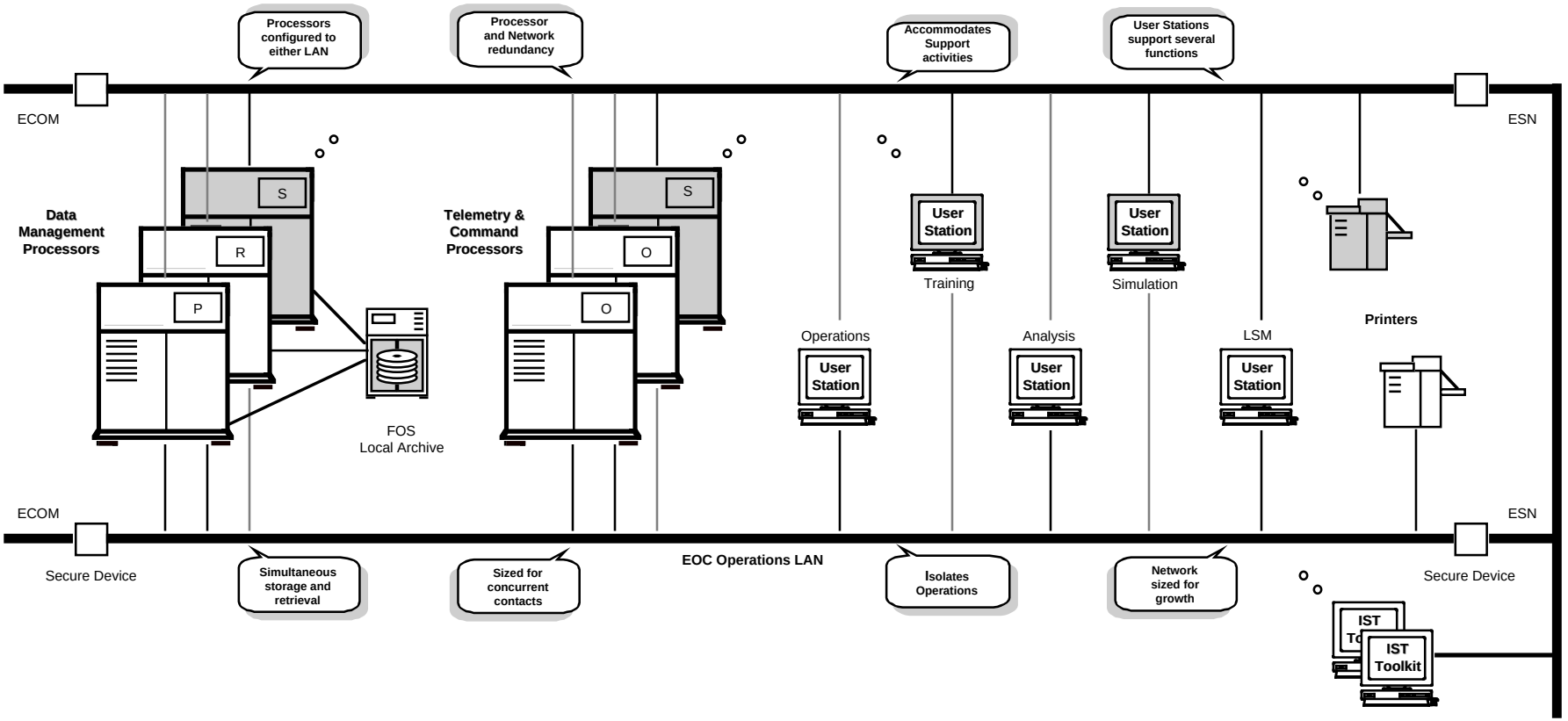
Time-ordered series of directives that are executed during a spacecraft contact.

• A directive can be either a ground directive or a directive to uplink a real-time command or a command load.

Pre-Planned Command Procedure

A set of commands which have been validated and stored as a procedure for use when needed.

FOS Hardware Architectural Framework



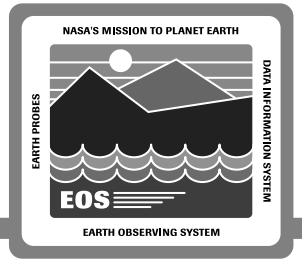
FOS Hardware Architectural Framework

FOS Network Characteristics	Benefits
Redundant Local Area Networks (LANs) for operations and support	- Facilitate quick recovery in case of network failure
Isolation of operations and support LANs	- Enable concurrent operations and support (i.e., training, testing,) activities without impacting operations
EOC Processors can be switched between LANs	- Provides operations flexibility - Facilitates failure recovery

FOS Hardware Architectural Framework

FOS Hardware Characteristics	Benefits
Network sized to support multiple spacecraft	- Additional hardware can be added without impacting hardware or software architecture - Network analysis based on system requirements and heritage performance analysis
EOC Processors include primary, redundant, and support components	- Provides operations flexibility - Facilitates failure recovery

FOS Hardware Architectural Framework



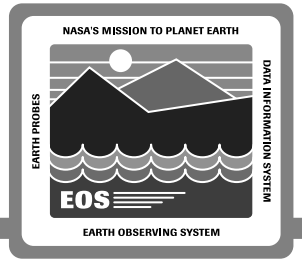
Telemetry and Command Processor

- **Provides primary telemetry and command processing capabilities within the EOC**
- **Significant drivers**
  - **Real-time performance**
  - **Process multiple, concurrent real-time contacts, simulations, and replays**
  - **Telemetry processing**

    Real-time - 50 kbps

    Replay - 150 kbps
  - **Command processing (up to 10 kbps)**

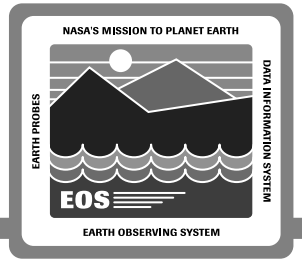
FOS Hardware Architectural Framework



Data Management Processor

- **Provides primary storage and retrieval capabilities within EOC**
- **Significant drivers**
  - **Disk I/O and disk access**
  - **Archive data at fairly high rates (i.e., 1.544 Mbps)**
  - **Handle simultaneous requests for retrieval of historical data and provide file management services**
  - **Modeling results - key storage items are quick-look data, housekeeping telemetry**

FOS Hardware Architectural Framework



FOT User Stations

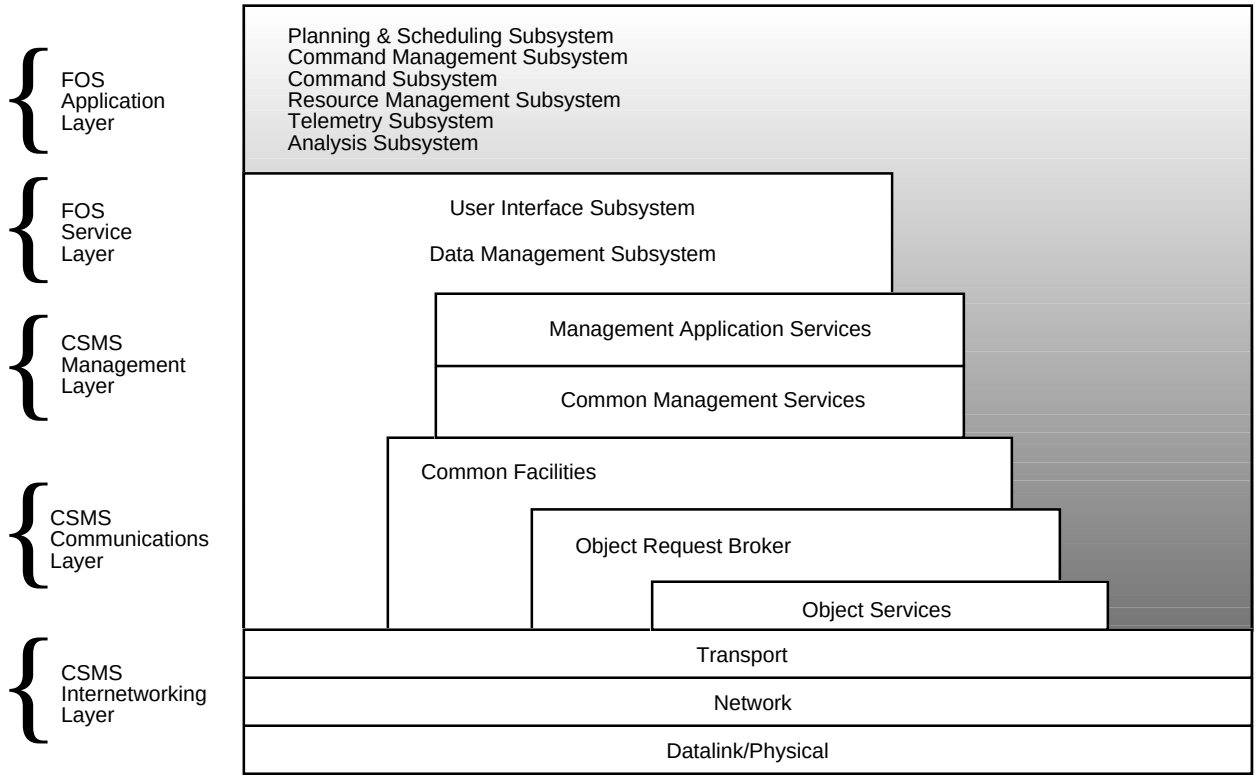
- Provides user interface capabilities for FOT mission
- Provides access to Scheduling, Real-Time Operations, and Analysis functions
- Significant drivers
  - Display spacecraft and instrument data in real-time or faster (i.e., replays)
  - Provide quick user response
- Local System Management (LSM) performs network and system management services and is a component of the CSMS Management Subsystem (MSS)
- User Station could be extended to accommodate Decision Support System, which is being prototyped

FOS Hardware

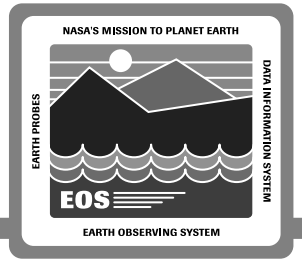
IST

- Consists of ECS-provided software toolkit allowing a remote instrument scientist to access flight operations capabilities
  - Direct commanding is not available via the IST
  - PI/TL submits command requests to the EOC
- Runs on PI/TL provided platform
  - Low-end Unix-based workstation
  - Further information on specifications will be at Release A PDR
- Each instrument site can have unlimited copies of the toolkit
- A constraint exists on the number of concurrent users
  - Analogous to COTS multi-user run-time license

FOS Software Architecture



FOS Software Architecture



Layered approach encapsulates services provided by one layer from the other layers

- **Facilitates technology insertion**

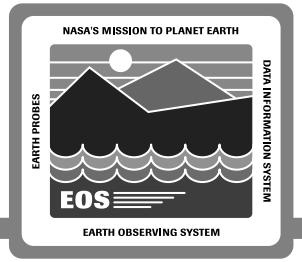
Use of standards to allow FOS to be expandable and flexible with current and future technology (e.g., Motif, POSIX)

- **Portability between computer platforms**

FOS service layer

- **Data Management Subsystem and User Interface Subsystem provide general capabilities and functions that are used by the other six FOS subsystems**

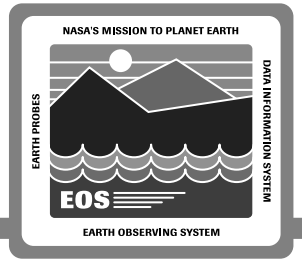
FOS Software Architecture



Software development principles provide framework for evolution and reuse

- **Encapsulation**
  - **Enables capability to change FOS functionality in one object class without disturbing the design of related objects**
  - **e.g., Implement Requirements change to the telemetry packet object would be isolated to that object class; i.e., would not impact the telemetry algorithm object**
- **Inheritance**
  - **Enables expandability and extensibility of an FOS capability without duplicating development efforts**
  - **e.g., Flight software load for PM-1 S/C would use AM-1 object and only add new functionality required for PM-1**

FOS Software Architecture



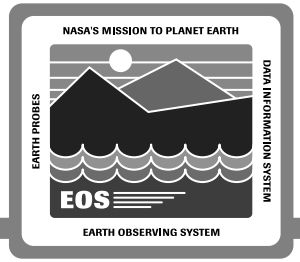
Software development principles provide framework for evolution and reuse (cont.,)

- **Clear definition of interfaces**
  - **Hide internal processing method of a source object from the destination objects' knowledge**
  - **Source object can modify its processing method**
  - **Interface objects used between FOS subsystems and between FOS subsystems and external interfaces**

Security

- **CSMS provides security services to ensure access to FOS is limited to authorized users**
- **FOS ensures command capability is limited to one authorized operator per spacecraft**

FOS Distributed Processing



Telemetry and Command Processor

Real-Time Operations
- Telemetry
- Command
- NCC and EOC configuration

Analysis
- Telemetry real-time
- Telemetry history
- Event history

Data Management Processor

Scheduling
- Storage and retrieval
  - Schedules
  - Loads
  - Ground scripts

Real-Time Operations
- Storage and retrieval
  - Telemetry
  - Events
  - Data Base
    - -- Telemetry
    - -- Command

Analysis
- Storage and retrieval
  - Telemetry
  - Events
  - Data Base
    - -- Telemetry
    - -- Command

User Station

Scheduling
- Display and receive user input
  - Schedules
  - Timelines
  - Preplanned Command procs

Real-Time Operations
- Display and receive user input
  - Telemetry data
  - Ground scripts
  - Commands
  - Events

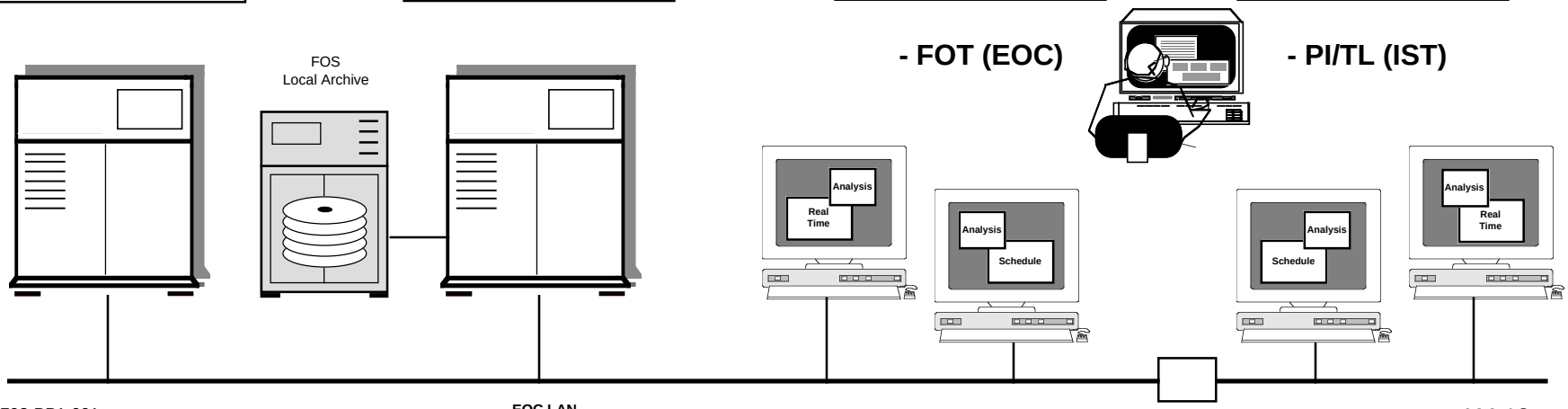
Analysis
- Display and receive user input
  - Telemetry data
  - Plots, graphs, reports
  - Events

Instrument Support Terminal

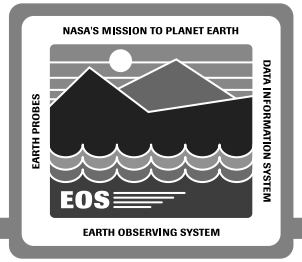
Scheduling
- Display and receive user input
  - Schedules
  - Timelines
  - Preplanned Command procs

Real-Time Operations
- Display and receive user input
  - Telemetry data
  - **Command requests**
  - Events

Analysis
- Display and receive user input
  - Telemetry data
  - Plots, graphs, reports
  - Events



FOS Distributed Processing



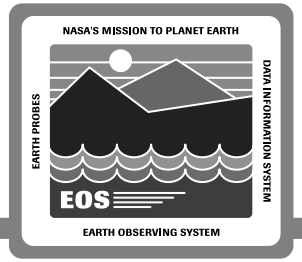
Scheduling, Real-Time Operations, and Analysis functions are distributed among the EOC computers and the IST

- **Time-critical operations are separated from off-line operations**
- **Distributing processing load optimizes performance**
- **Data Management Processor provides access of FOS data to all authorized users**

User Station and IST provides source for Flight Ops Team and PI/TL to enter requests

- **Any User Station and IST can perform any authorized function**
- **User can perform scheduling and history plots concurrently from the same User Station or IST**

FOS Operational Configurations



FOS provides users the flexibility to perform different operational scenarios by connecting to logical strings

Operational scenarios

- **Real-time contact**
- **Spacecraft simulation**
- **Replay of historical telemetry**

Operational flexibility

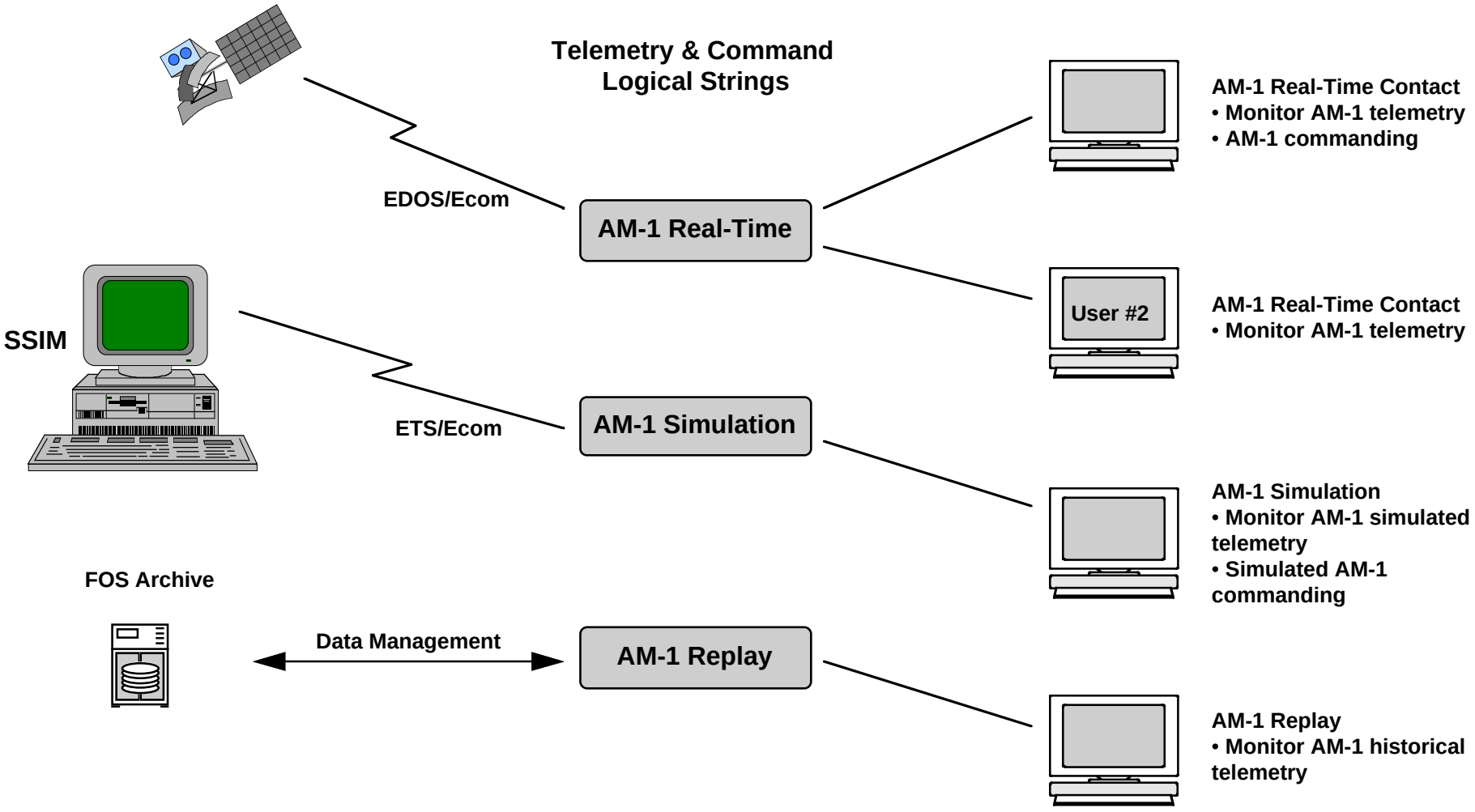
- **Multiple users can connect to the same logical string**
- **A single user can connect to multiple logical strings**

A set of hardware components can host multiple logical strings concurrently

- **Design based on heritage performance data and preliminary modeling analysis**

SDS- 5.2.3

FOS Operational Configurations



FOS - Multiple Spacecraft and Instruments

FOS design

- **Provides capability to support multiple spacecraft and instruments concurrently**
- **Logical string concept can be extended to accommodate additional spacecraft and instruments to the FOS**

Single operator can monitor multiple spacecraft simultaneously

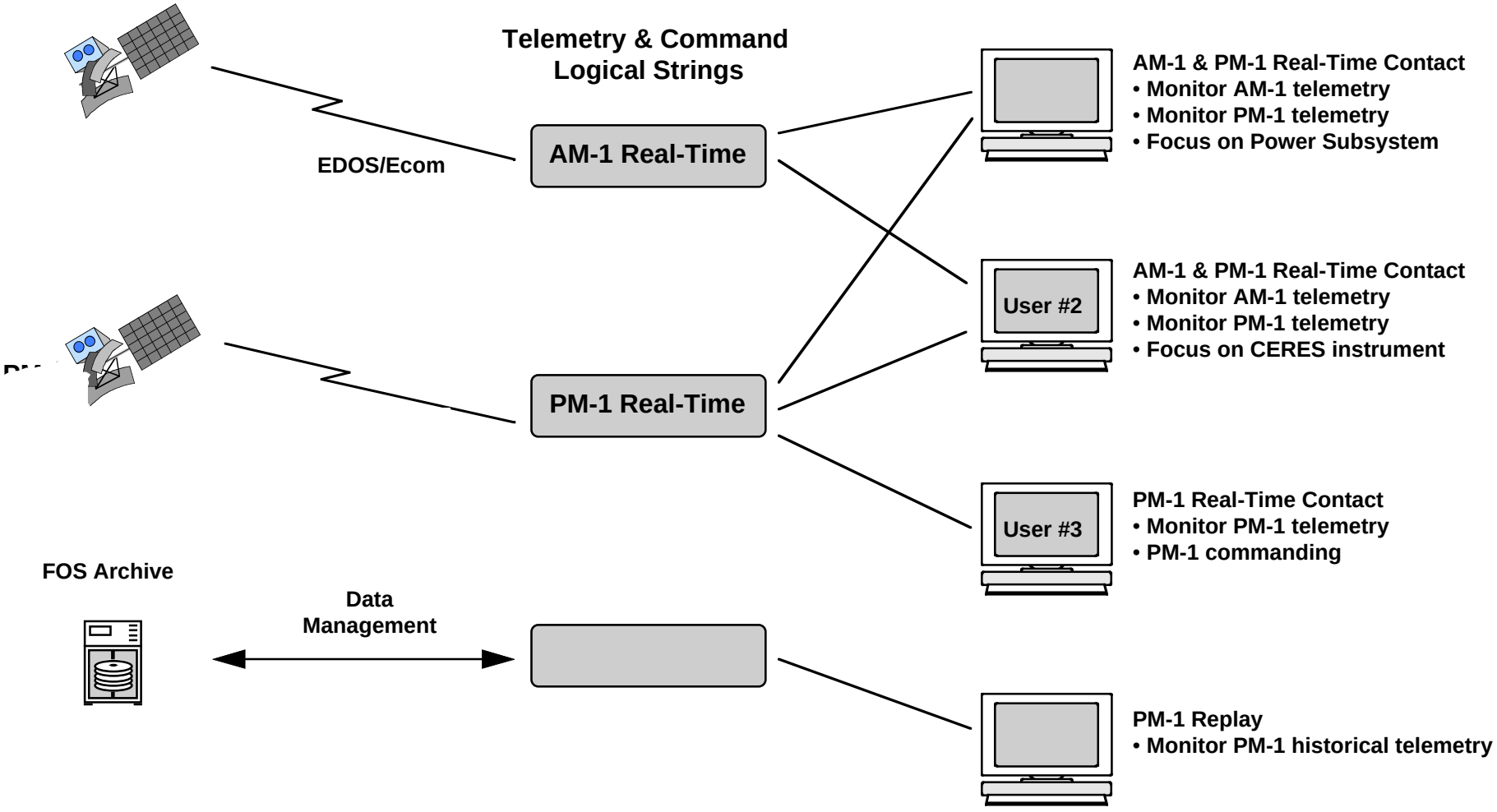
- **Operator could monitor Power Subsystem for AM-1 and PM-1**

Single operator can monitor same instrument for multiple spacecraft simultaneously

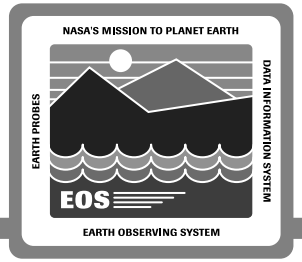
- **Operator could monitor CERES instrument telemetry from AM-1 and PM-1**

SDS- 5.2.3

FOS Multiple Spacecraft and Instruments



FOS Failure Recovery



Redundant logical string can be established operationally to facilitate failure recovery

- **Active logical string processing telemetry and sending commands to the spacecraft**
- **Redundant logical string is receiving and processing telemetry data**
- **Redundant logical string does not have privilege to send commands to the spacecraft**

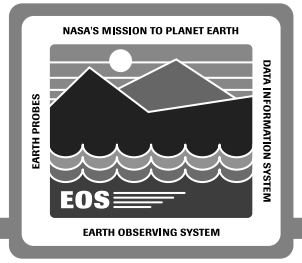
Telemetry and Command Processor Failure

- **Operator requests connection to redundant logical string, which is hosted on a second operational Telemetry and Command Processor**
- **Operator requests that command authority be re-established through new active logical string**

Data Management Processor Failure

- **Operator requests that redundant Data Management Processor become primary FOS storage and retrieval unit**

FOS Failure Recovery



User Station Failure

- **Operator uses a different User Station to perform operational tasks**
- **Operator connects to applicable logical string(s)**
- **Operator requests command authority, if Command Activity Controller**

Network Failure

- **Support activities are suspended**
- **Support LAN becomes operational LAN**
- **Operational processors switch LAN connections**
- **Logical string(s) re-established and processing resumes**

IST Characteristics

Requirements

- **IST is not a mission critical function** → **EOC has ultimate responsibility for health and safety of instruments**
- **IST provides PI/TL capability to participate in mission operations** → **IST can perform authorized scheduling, real-time, and analysis functions**

Design Drivers

- **Produce a standard IST** →
  - **- Hardware requirements low cost and industry standard**
  - **- Configurable by the user**
  - **- Not modifiable by the user**
- **Protect EOC from unauthorized access** →
  - **Updates limited to instrument's data**
  - **Authorized user's lists:**
  - **- Run IST software**
  - **- Run IST software in update mode**
  - **(P&S and DB updates, command requests)**

IST Characteristics

Design Drivers

Protect EOC from performance burden imposed by ISTs

→ - Perform modeling analysis based on number of ISTs and functions performed

Policy

Every instrument guaranteed access to one IST

→ Run-time licenses:
- Each instrument guaranteed one seat
- Floating pool of available seats

Allow for multiple ISTs per instrument

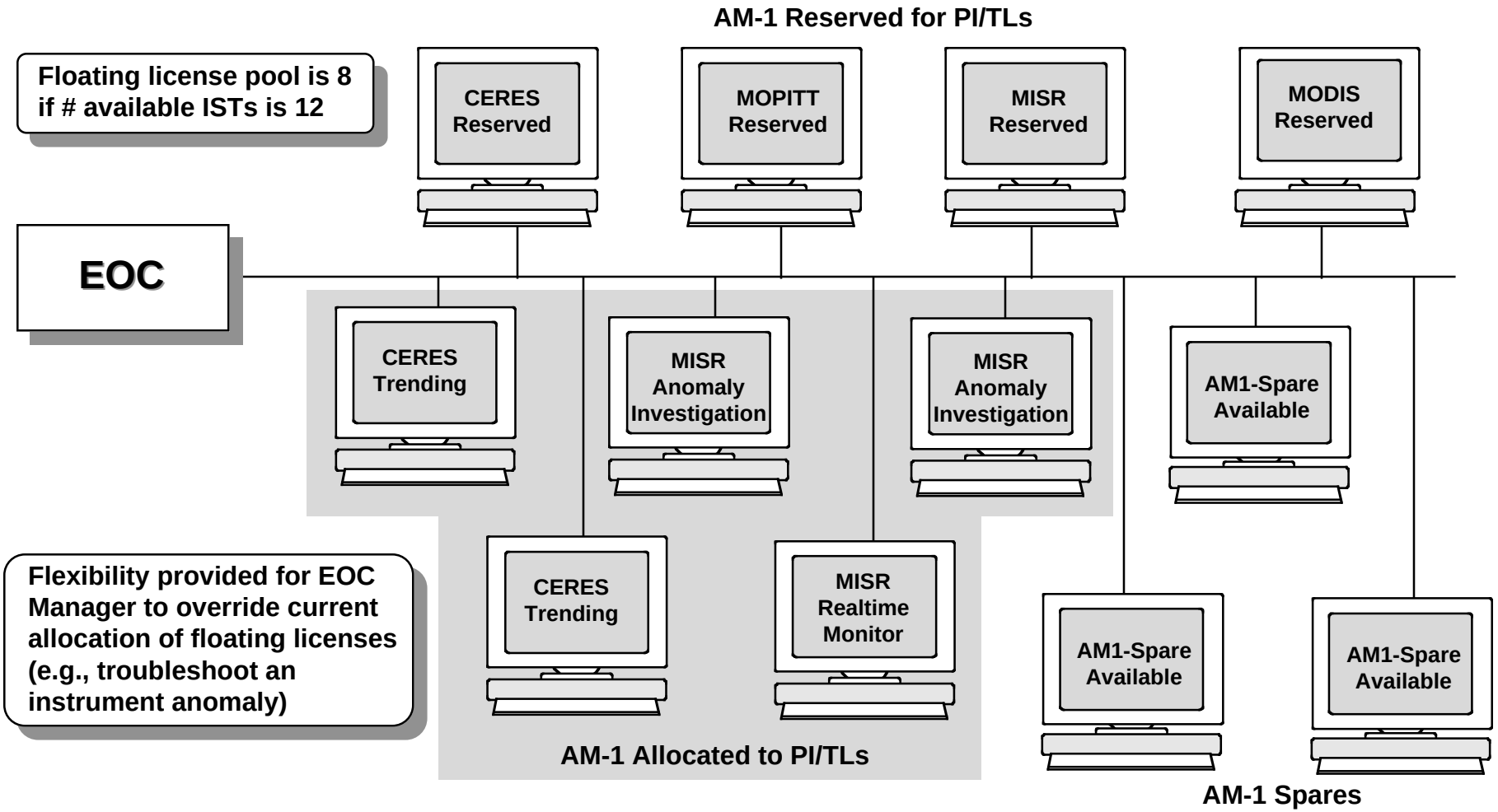
→ Run-time licenses:
- Each instrument guaranteed one seat
- Floating pool of available seats

Limit concurrent users to 12-15 range for AM-1

→ Range based on:
- Current operations concept
- Specific range required to perform modeling analysis

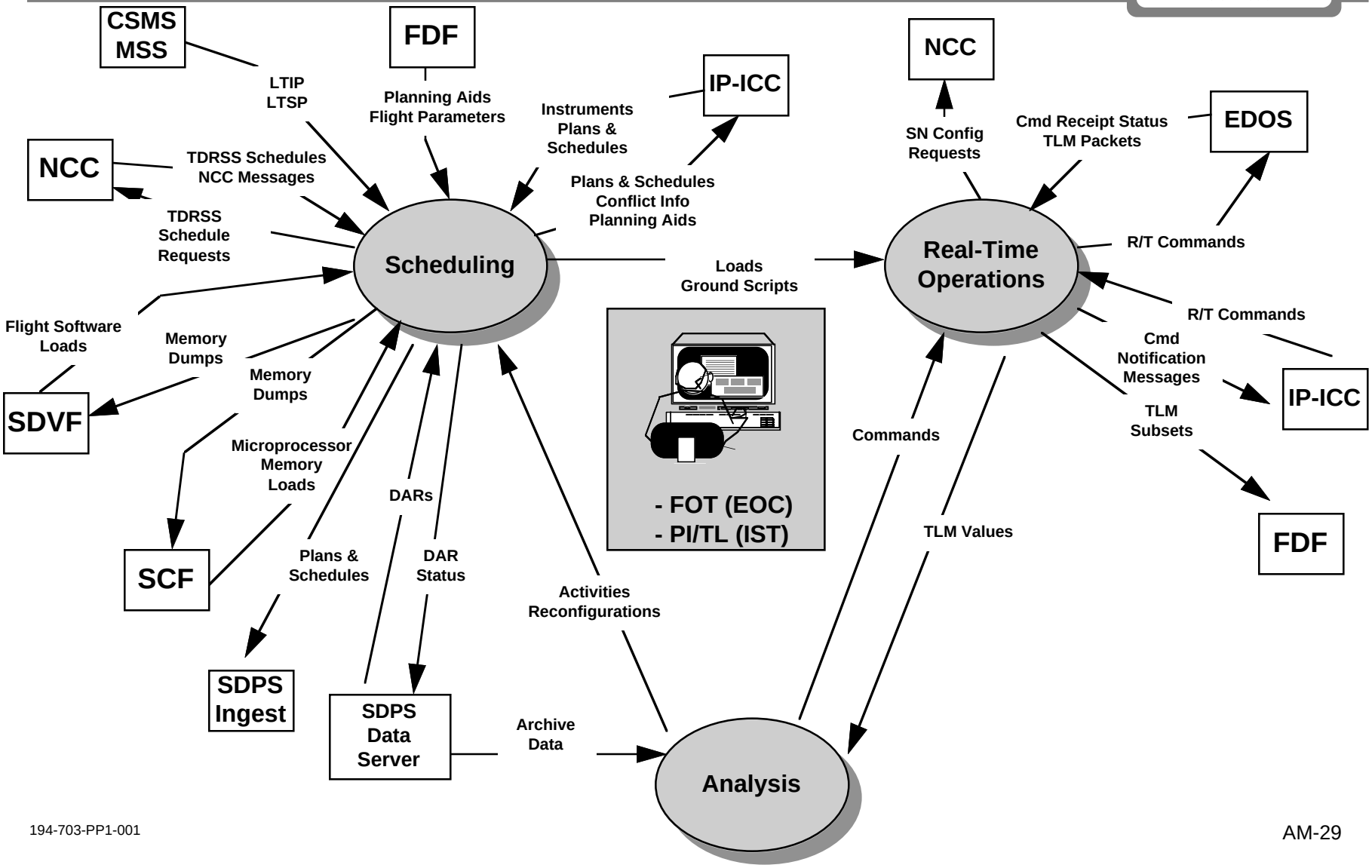
SDS- 5.2.5

Sample AM-1 IST Configuration



SDS- 5.1

FOS External Interfaces



FOS External Interfaces

Scheduling

- FDF - Planning aids provided for scheduling
- NCC - Establishes TDRSS times to schedule real-time contact activities
- IP-ICC - provide instrument schedules to EOC and receives scheduling info from EOC

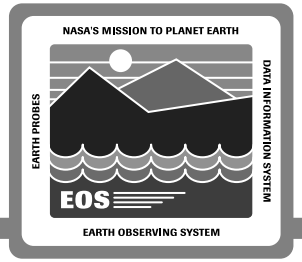
Real-Time Operations

- EDOS - sends telemetry to EOC and receives commands and command loads from the EOC
- NCC - receives SN configuration requests from the EOC
- FDF - receives telemetry subsets from EOC
- IP-ICC - sends commands for uplink via EOC and receives command notification status from EOC

Analysis

- SDPS Data Server - provides access to long-term FOS archive data

Key FOS Scenarios



Scheduling

- **Ingest and distribution of planning aids**
- **Establishment of TDRSS contact times**
- **Final scheduling**
- **Command load generation**

Real-Time Operations

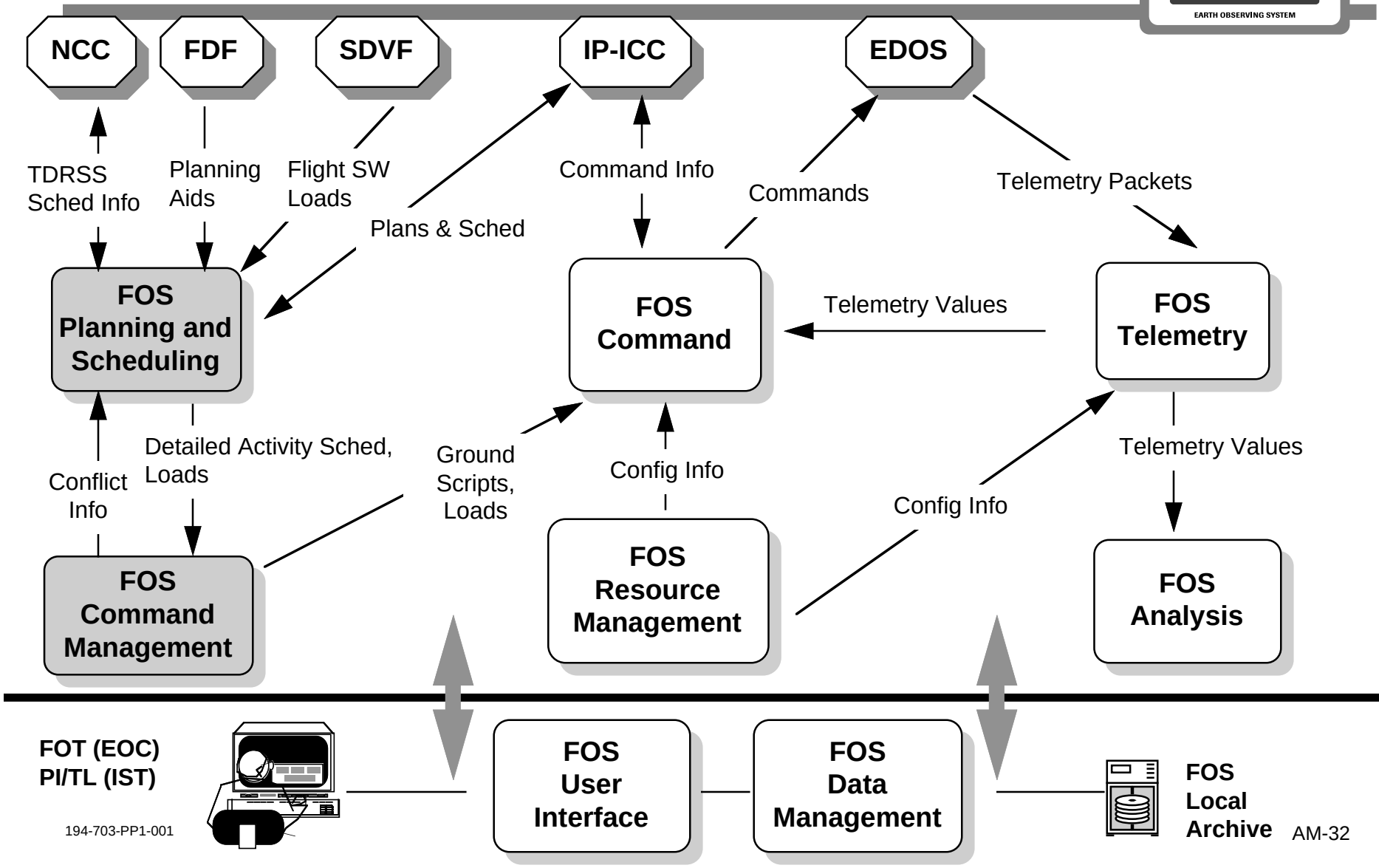
- **NCC and EOC configuration requests**
- **Command uplink and verification**
- **Telemetry monitoring**

Analysis

- **Anomaly detection**
- **Performance assessment**

SDS- 5.3

Scheduling Scenario



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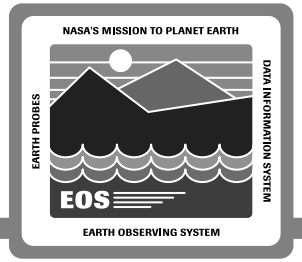
Scheduling Scenario



Ingest and distribution of planning aids

- **Receive planning aids from FDF**
- **Distribute to IP-ICC and science teams via IST**

Establishment of TDRSS contact times

- **TDRSS contact request submitted to NCC**
- **NCC sends contact schedule with any rejection info**

Final scheduling

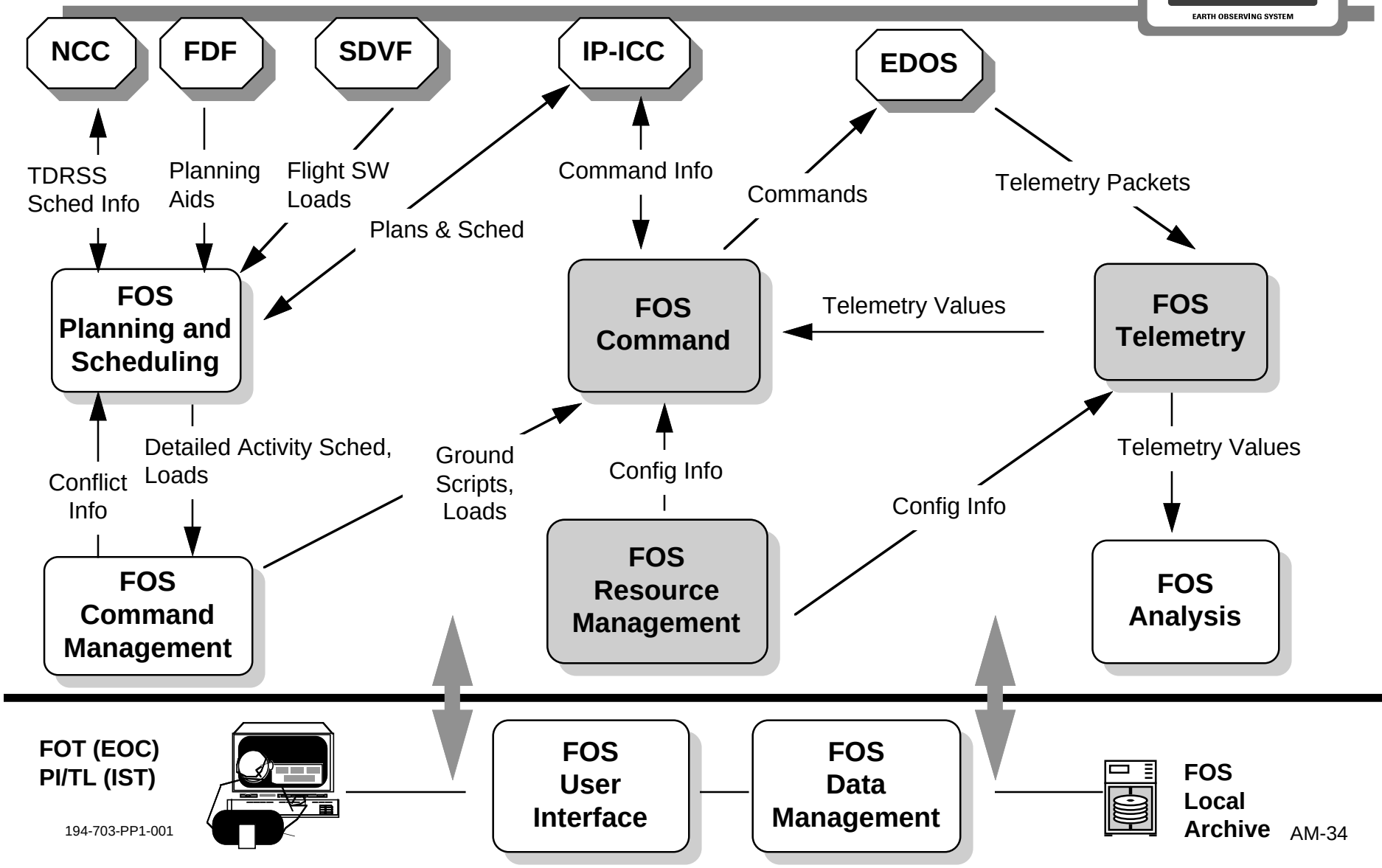
- **Scheduling of ground activities**
- **Generates integrated conflict free detailed activity schedule**

Command load generation

- **Generation of ground scripts and ATC loads**

SDS- 5.3

Real-Time Operations Scenario



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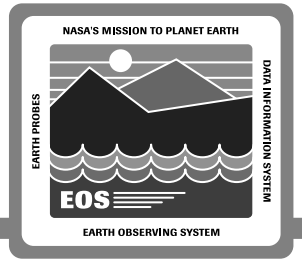
Real-Time Operations Scenario



EOC and NCC configuration requests

- **EOC processes user requests to establish logical string for a real-time contact**
- **NCC receives requests for space network configuration change from the EOC, if required**

Command uplink and verification

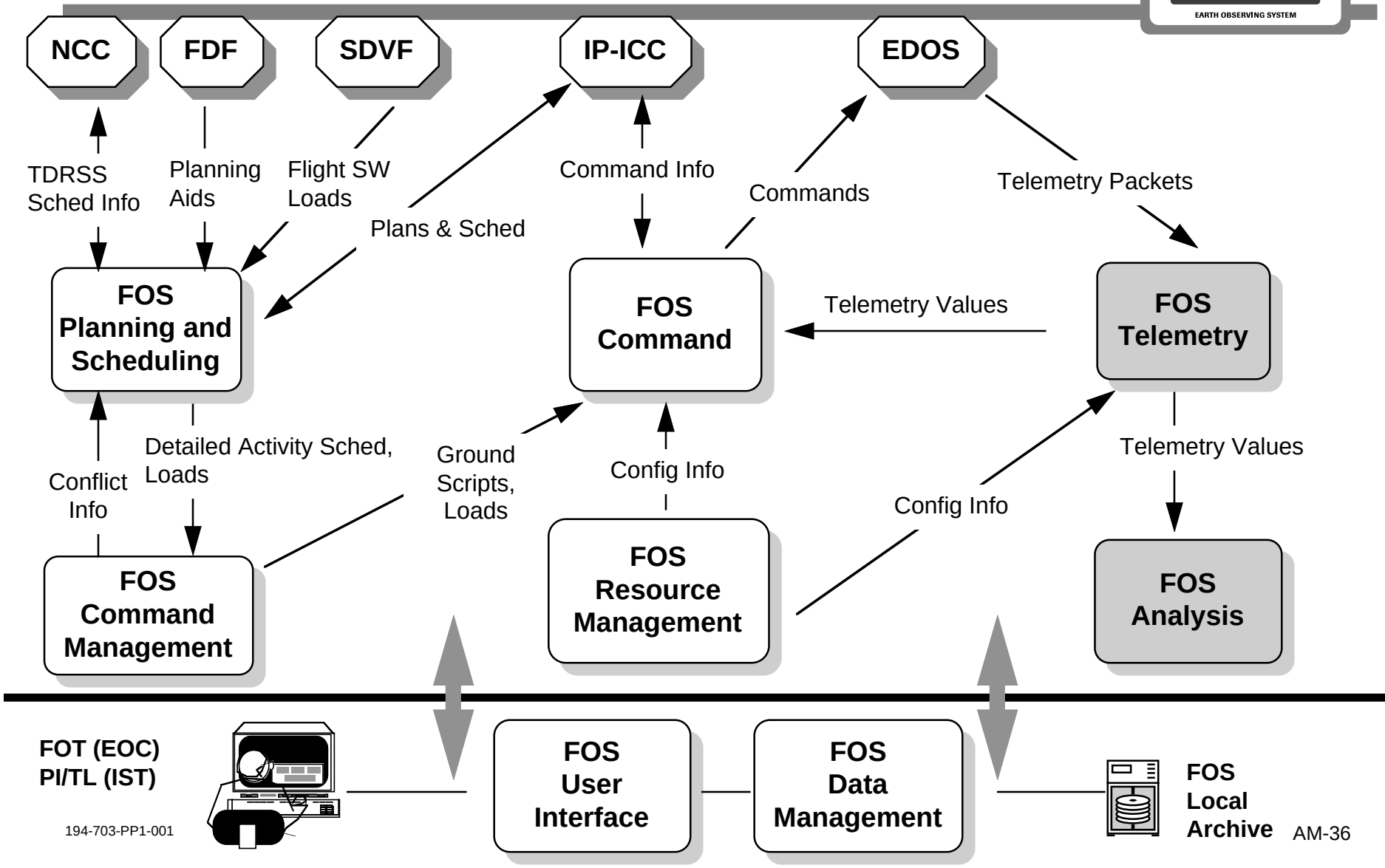
- **Validate, build, and transmit commands to S/C via EDOS**
- **Verify commands and command loads from CLCWs and housekeeping telemetry**

Telemetry monitoring

- **Receive and process housekeeping telemetry from S/C via EDOS**
- **Display telemetry data and identify limit violations**

SDS- 5.3

Analysis Scenario



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Analysis Scenario

Routine operations

- **Analyze real-time and historical telemetry**
- **Assess spacecraft subsystem and instrument performance via plots, reports, statistical analysis, and trend analysis**

Anomaly investigations

- **Identification of resource degradation through routine operations analysis**
- **Use analysis tools to assist in determining scope of the problem and determine corrective action**
- **If time critical, then corrective action implemented during next available contact**
- **If not time critical, then corrective action implemented into scheduling operations**